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A VERTICAL SUCCESSION OF COLLEMBOLA AND THEIR RELATIONSHIP TO OTHER ARTHROPODS IN IRISH WOODLAND

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The vertical succession of Collembola was investigated in deciduous beech woodland (*Fagus sylvatica* L.). The ground litter species were compared with those of pine (*Pinus sylvestris* L.). Previous ecological work has been carried out on Collembola and Glasgow (1939) has observed the vertical migration of subterranean soil Collembola with changes in surface soil humidity and temperature. Gisin (1948) and Weis-Fogh (1948) worked on the horizontal succession of ground Collembola down to certain depths. The furcula was seen to be poorly developed in subterranean species. Davies (1928) showed that the longevity of certain Collembola was reduced in a dry atmosphere and more recently the phenology of a population (Milne, 1962) and the relationship of temperature to populations of soil Collembola have been discussed (Macfadyen, 1952; Healey, 1967).

The work of Fager (1953, unpublished), Kempson *et al.* (1963) and Larkin & Elbourn (1964) on the microscopic arthropod fauna of ground and aerial oak branches at different heights in various parts of Wytham Woods, Berks., has been reviewed by Elton (1966). No work to date appears to have been published on the vertical distribution of Collembola in beech woodland or on their ecology in Ireland.

The investigation was carried out during late October, 1965, to early January, 1966. The fluctuating population of Collembola is at a higher level at this time of year than at other times (Macfadyen, 1952; Milne, 1962 and others) and decreases after February. Beech is not native to Ireland and pine is frequently planted, but the former provides woodland representative of the deciduous type.

Material and Methods

The beech woodland, near Stepaside, Co. Dublin, consisted of mature trees 20 to 30 m in height which had formed a deep litter of approximately 40 cm. The pine trees constituted a small grove adjacent to this woodland and were 4 to 5 m in height, immature, forming a litter approximately 10 cm in depth. A few Collembola which were large and active such as *Tomocerus* were observed by carefully turning over the surface litter to expose lower layers and separating the material. Individual specimens of the active species, *Entomobrya albocincta* Templeton, were seen on the bark surface of beech trunks, but none was seen on pine. Material was collected by taking beech samples from the ground and from various heights on the trees. Areas of bark from dead branches, growths and the dead and decaying aerial branches themselves were sampled from the trees. Moss from the trunk bases and rotting litter to a depth of 15 cm were taken from the ground (Table 1).

The smoothness of the bark on the beech trunks made it necessary to collect an adequate volume of sample material (dead branches and growths) from the lower heights. The sample material was placed in polythene collecting bags, the moss from the two trunk bases approxim-

ately filling a bag of 20 by 35 cm each. The bags were secured to prevent the loss of moisture from the material. No samples were taken from above 6 m, mainly for practical reasons and partly because airborne species (Glick, 1939 and Freeman, 1952 in Johnson, 1969) alone would probably have been present. Ground litter samples consisting of leaf-needles and samples of bark from up to one metre were taken from several trees in the pine grove.

TABLE 1.—SAMPLES TAKEN IN BEECH WOODLAND

Situation	Sample material	No. of samples	Height (m)
Ground	Leaf litter (to a depth of 15 cm)	12	0
Tree	Moss on trunk base	2	0–1.2
,,	Bark, growths and dead branches	2	1–2.1
,,	Dead branches and bark	2	2.1–3.6
,,	,, ...	1	3.9
,,	,, ...	1	6

TABLE 2.—THE OCCURRENCE AND PERCENTAGE FREQUENCY OF COLLEMBOLA AT DIFFERENT HEIGHTS IN BEECH WOODLAND NEAR STEPASIDE, CO. DUBLIN

Species of Collembola	Litter	Height (m) above litter surface 0–1.2	1.2–2.1	2.1–3.6	3.9	6
Isotoma olivacea	53.4	0.7				
Folsomia quadrioculata	22.1	0.1				
Lepidocyrtus lanuginosus	15.2	0.1				
Neanura muscorum	4.9	0.3				3.7
Dicyrtomina sp.	3.7					
Orchesella cincta	0.5					
Tomocerus minor	0.2					
Onychiurus ambulans fimetarius agg.		89.2				
Isotoma sensibilis		9.1			10.9	
Anurophorus laricis		0.4	14.3	66.7	17.3	59.3
Entomobrya nivalis		0.1	39.6	14.8	6.4	11.1
E. albocincta		0.1	46.2	14.8	60.9	25.9
Hypogastrura sp.		0.1		3.7	4.5	
Total no. of Collembola	408	4687	91	27	156	27
No. of samples	12	2	2	2	1	1

TABLE 3.—THE OCCURRENCE AND PERCENTAGE FREQUENCY OF COLLEMBOLA IN THE LITTER AND ON THE TRUNK BASES IN A PINE GROVE NEAR STEPASIDE, CO. DUBLIN

Species of Collembola	Litter	Trunk base (up to 1 m)
Isotoma olivacea	63.4	
Folsomia quadrioculata	11.0	
Lepidocyrtus lanuginosus	12.8	10.5
Neanura muscorum	8.0	
Dicyrtomina sp.	3.5	1.6
Tomocerus longicornis	0.9	
Entomobrya nivalis	0.3	66.9
E. albocincta		4.0
Anurophorus laricis		16.9
Juveniles	0.3	
Total no. of Collembola	1168	124
No. of samples	12	3

The insects were extracted in Tullgren Funnels and preserved in 70 per cent alcohol, giving a recovery rate of about 80 per cent of the population (Gabbutt, 1959). Different species were mounted whole and determinations were checked by Lawrence (1968). The nomenclature was based on Goto & Lawrence (1964).

Results

The occurrence and frequency of Collembola

The percentage frequency of species of Collembola, other Insecta and invertebrates was estimated by counting the number of individuals of each species or group at the different levels. The beech woodland yielded 13 species of Collembola and the pine nine (Tables 2 and 3).

In beech woodland, species found in the litter were not represented on the trunks or in decaying tree material, while both tree and litter species were represented in the moss at the base of the trunks together with another species (*Onychiurus ambulans/fimetarius* agg.) which was abundant and confined here (fig. 1). The ground litter was occupied mainly by *Isotoma olivacea* Tullberg. *Folsomia quadrioculata* (Tullberg) and *Lepidocyrtus lanuginosus* (Gmelin) were also present. *Entomobrya albocincta* and *Anurophorus laricis* Nicolet were found above one metre on beech trunks and their percentage frequency may depend upon the proportion of dry or damp tree material sampled.

Three of the pine litter species, *Entomobrya nivalis* (L.), *Lepidocyrtus lanuginosus* and *Dicyrtomina* sp. were present on the trunk base below one metre. *Anurophorus laricis* was present, as in beech, only on the trunks. *Tomocerus longicornis* (Müller) was present in pine litter; but in beech, only *T. minor* (Lubbock) was to be found together with *Orchesella cincta* (L.). Both the albino and normal (blue) form of *Neanura muscorum* (Templeton) were found in the litter of both tree species and in the moss on the trunk bases of beech (one specimen was collected from the trunk). *E. nivalis* was collected from the leaf-needle litter of pine, but was absent from that of beech.

The species diversity was determined in the samples made up of different numbers of individual insects at each height. Attempts to quantify diversity have been devised by Fisher *et al.* (1943) and Margalef (1951 in Williams, 1964). Margalef gave a simplified formula and Fisher has shown that:

$$S = a \log_e (1 + \frac{N}{a})$$

where S (number of species) is given in terms of a (diversity) and N (number of individuals). If the sample is large, 1 can be neglected in comparison with N/a.

The equation was solved using the table of Fisher *et al.* (1943) in which $\log_{10} N/a$ is given in terms of $\log_{10} N/S$, when N and S are known.

TABLE 4.—THE NUMBERS OF INDIVIDUALS AND SPECIES OF COLLEMBOLA IN BEECH AND PINE AT DIFFERENT HEIGHTS SHOWING THE SPECIES DIVERSITY AND ITS PERCENTAGE ERROR

Tree type	Height (m)	Individuals (N)	Species (S)	Species Diversity (a)	Percent Error
Beech	Litter	408	7	1.20	17
	0–1.2	4687	10	1.21	11
	1.2–2.1	91	3	0.59	25
	2.1–3.6	27	4	1.23	37
	3.9	156	5	0.98	22
	6.0	27	4	1.23	37
Pine	Litter	1168	7	0.99	12
	0–1.0	124	5	1.06	23

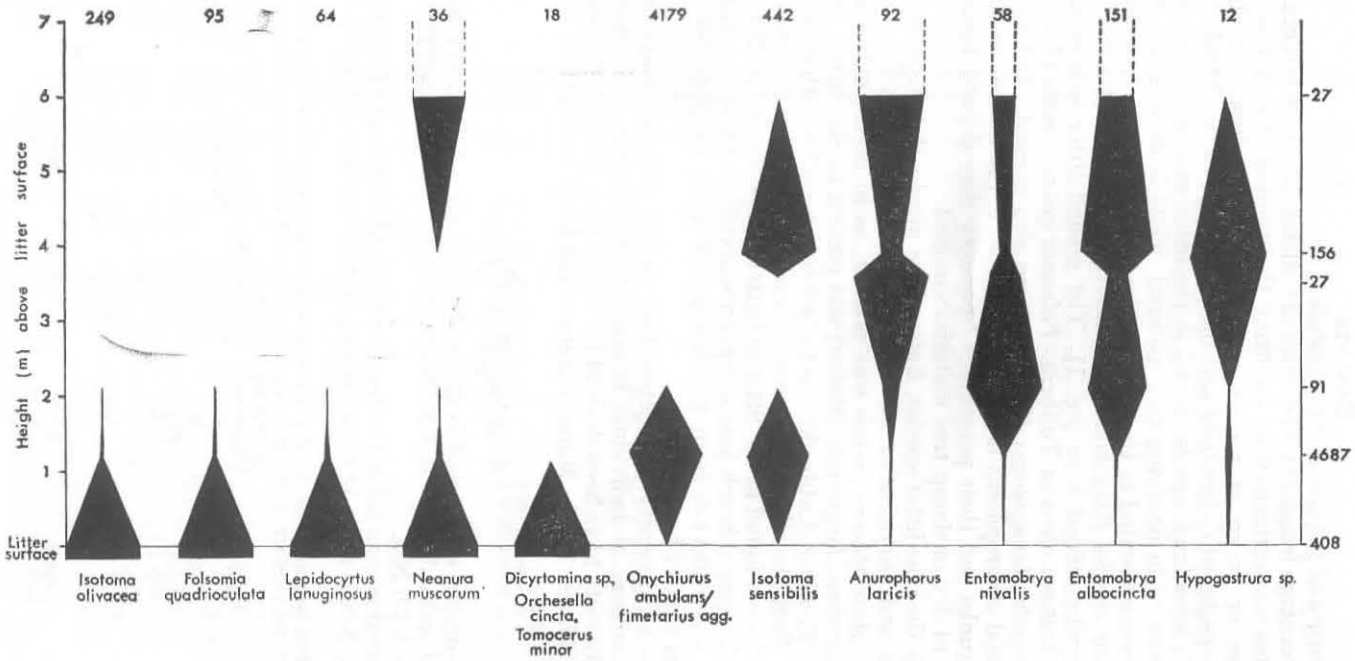

Fig. 1.—The vertical succession of Collembola, showing percentage frequency, in relation to height in beech woodland near Stepaside, Co. Dublin. Individuals of each species and at each height are represented numerically above and to the right respectively. The kite diagram was based on equivalent percentage values for each species at the different heights.

The percentage error in the diversity, determined from a table (Williams, 1964), and the diversity of Collembola species in beech woodland at different heights and in a pine grove are dependent also on the numbers of species and individuals in the sample (Table 4).

There was greater diversity of species in the litter of beech than in pine (1.20 and 0.99), although this is not significant. The results in general suggest a remarkable constancy in diversity although at 1.2 to 2.1 m on beech the species diversity was lower. This may have depended on the sampling procedure and size and on the variation in moisture content of the sample material, and notwithstanding the variation in numbers of individuals at each height.

The relationship of Collembola to other arthropods

An interrelationship in percentage frequency existed between the Insecta and Arachnida at different heights in beech woodland (fig. 2).

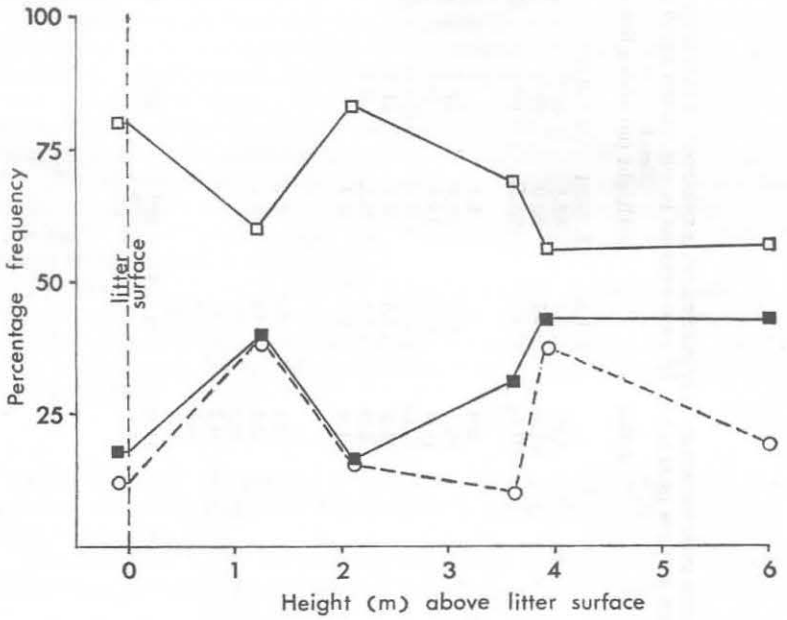

Fig. 2.—The relationship between the arachnids (open squares) and the insects (closed squares), showing the proportion comprising Collembola (broken line), at different heights in beech woodland near Stepaside, Co. Dublin.

The Collembola made up the majority of insects in the litter and at some heights. Thysanoptera were more abundant at others, probably having flown in from surrounding fields to overwinter.

The arachnids consisted mainly of Acarina. These made up a mean proportion of the arachnids of 98.4 per cent, but Pseudoscorpionidae were also present. The mites were the most common of the arthropods collected. Whenever the number of arachnids was low, the number of insects was proportionally greater. The percentage frequency of these and other arthropods from beech and pine is shown in Table 5.

TABLE 5.—THE OCCURRENCE AND PERCENTAGE FREQUENCY OF ARTHROPODS AT DIFFERENT HEIGHTS IN WOODLAND NEAR STEPASIDE, CO. DUBLIN. TOTALS FOR A CLASS IN ITALICS. IN PARENTHESIS IS THE ORDER PERCENTAGE WITHIN A CLASS

Invertebrate groups	Litter	Beech Height (m) above litter surface					Pine Litter	Pine Trunk base on trees (up to 1 m)
		0–1.2	1.2–2.1	2.1–3.6	3.9	6		
CLASS ARACHNIDA	*83.0*	*59.7*	*82.8*	*68.6*	*55.7*	*56.8*	*60.6*	*77.5*
O. ACARINA	81.0	59.7	82.0	68.6	53.3	56.1	60.4	72.6
	(97.6)	(100)	(98.5)	(100)	(95.7)	(98.7)	(99.6)	(93.7)
O. ARANEIDA							0.2	4.9
O. PSEUDOSCORPIONIDAE	2.0		1.3		2.4	0.7	0.1	
CLASS INSECTA	*16.0*	*40.0*	*16.6*	*31.4*	*44.2*	*43.2*	*39.0*	*22.5*
O. COLLEMBOLA	11.9	39.6	15.8	9.6	37.8	19.4	32.8	16.0
	(74.6)	(98.9)	(94.8)	(30.7)	(85.7)	(45.0)	(84.0)	(70.9)
O. THYSANOPTERA	1.7	<0.1	0.2	21.4	4.8	22.3	2.6	1.3
O. DIPTERA	1.0	<0.1	0.3	0.4	0.7	1.4	<0.1	4.5
O. COLEOPTERA	1.9	0.4	0.3		0.7		3.5	0.6
O. LEPIDOPTERA							<0.1	
O. HYMENOPTERA								0.1
CLASS CRUSTACEA	*0.5*	*<0.1*	*0.2*				*0.1*	
S.O. ISOPODA	0.5	<0.1	0.2				0.1	
CLASS MYRIAPODA	*0.3*	*<0.1*					*0.1*	
S.C. CHILOPODA	0.2	<0.1					0.1	
S.C. DIPLOPODA	0.1	<0.1						
OTHER PHYLA	<0.1	<0.1					<0.1	
Total no. of Arthropoda	3424	11,821	577	280	412	139	3556	777
No. of samples	12	2	2	2	1	1	12	3

Discussion

The distribution and abundance of Collembola are dependent upon their anatomical and physiological adaptations to the particular microhabitat. They have a preference for a damp habitat as their longevity is reduced in a dry atmosphere (Davies, 1928). The temperature changes are perceived through the antennae (Strebel, 1932) and they probably have a temperature preferendum as shown for other insects by Deal (1941). The claws on the tarsi are furnished with more teeth in those species occurring in surface litter or on the trunks where the capacity for climbing is required, such as in *Folsomia quadrioculata* and *Entomobrya albocincta* in beech. In a ground litter species, *Isotoma olivacea*, which was found in damp situations in rotting leaf litter, the furcula is poorly developed and the tarsal claws simple which probably prevent climbing. *Onychiurus ambulans/fimetarius* agg. which occurs in abundance in damp moss is unlikely to be able to withstand desiccation. The presence of *Neanura muscorum*, *Hypogastrura* sp. and *Isotoma sensibilis* Tullberg on the trees, which are species without or with reduced furculae and simple tarsi, may be explained by their airborne transportation (Freeman, 1952 and Glick, 1939 in Johnson, 1969).

The species diversity at different heights in beech and pine was remarkably constant and there was little difference in the presence of litter species in either. *Tomocerus minor* was present in beech and *T. longicornis*, which may be more tolerant to the toxins and which may not be able to compete with the larger *T. minor*, was present in pine. The absence of *O. ambulans/fimetarius* agg. from the trunk bases of pine was related to the presence of the moss habitat in beech. Above 1.2 m on beech trunks, the habitat was similar to that on the trunk bases of pine. *Entomobrya nivalis* was apparently more abundant on pine than on beech trunks, while *E. albocincta* was commoner on beech. The material sampled from pine was drier and this may explain the lower frequency of *Anurophorus laricis*. *Lepidocyrtus lanuginosus* was present on the trunk of pine and in the litter of both tree species.

A predator/prey relationship may be reflected by the interrelated variation in proportions of the arachnids and insects. Herbivorous species of mites may compete for food and refuges with Collembola, but carnivorous mites prey on smaller organisms, including Collembola, which would probably decrease in numbers correspondingly.

Summary

Ground litter and tree samples of moss, bark and dead branches were taken from beech woodland, and ground litter and trunk base bark samples from a pine grove. Collembola and other arthropods were extracted in Tullgren Funnels and preserved in 70 per cent alcohol. The percentage frequency of Collembola and other groups was related to different heights and the species diversity was shown to be approximately constant for Collembola in both tree types. An interrelationship in proportions was shown to exist between the insects (mainly Collombola) and the arachnids (98 per cent mites). This may represent a predator/prey relationship or competition for refuges between the two groups.

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